Chapter 97: Diagnostic Imaging of the Larynx

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The radiologist can play an important role in the evaluation of upper airway disorders in children and adults, often providing unique and useful diagnostic information directly affecting the management of the patient (Macpherson and Leithiser, 1985; Strife, 1988). Traditionally, the evaluation of the airway has included plain-film radiography, barium studies, and fluoroscopy, but computed tomography (CT) and more recently magnetic resonance imaging (MRI) have become the procedures of choice for defining mass lesions and traumatic abnormalities. These procedures can supplement the findings at laryngoscopy when additional diagnostic information is required for treatment planning.

Normal Airway

Technique

Except in rare circumstances, the plain-film examination of the airway should include anteroposterior and lateral radiographs of the pharynx as well as the laryngotracheal air column. In cooperative patients these films should be exposed uring inspiration with the patient upright, since acute respiratory obstruction may be exacerbated in the recumbent position. Although conventional soft tissue techniques are often adequate, high-kilovoltage magnification technique with selective filtration will result in better visualization of the airway with improved air-soft tissue interfaces (Joseph t al, 1976; Lallemand et al, 1973; Maguire et al, 1965). Xeroradiography also can provide excellent images of the airway because of edge enhancement, but the technique delivers a higher radiaton dose compared with conventional soft tissue films (Doust and Ting, 1974; Rosenfiel et al, 1979). This increased exposure rarely results in greater diagnostic information. In situations where plain films were inconclusive, fluoroscopy, plain tomography, and barium studies of the esophagus may be require to resolve the problem. Abnormal cord motion or swallowing mechanisms, vascular impressions, mass lesions, or nonopaque foreign boies are best evaluate by these methods.

Anatomy

The lateral radiograph is the cornerstone radiograph in evaluating the upper airway. This view is excellent for identifying the tongue, adenoids, tonsils, epiglottis, aryepiglottic folds, piriform sinuses, laryngeal ventricle, and subglottic trachea (Fig. 97-1, A). The anteroposterior airway is excellent for examining the glottic and subglottic areas (Fig. 97-1, B). In quiet respiration the vocal cords are abducted and the width of the upper airway is almost equal to that of the trachea. With phonation (e) the vocal cords adduct, resulting in narrowing at the glottic area. However, narrowing of the subglottic area should be considered abnormal.

The pediatric airway can demonstrate considerable variability in contrast to adults. Therefore one has to be acquainted with the normal airway anatomy before attempting to recognize pathologic conditions. This requires first of all that the patient be properly positioned for the study. The lateral airway radiograph must be obtained as much as possible in full inspiration with the neck extended. If the study is performed during expiration or with forward flexion of the neck, the retropharyngeal soft tissue in children bulges anteriorly and may simulate a retropharyngeal mass (Fig. 97-2; Brenner, 1964).

Other areas that can present significant problems in evaluation of the airway include the size of the adenoids and tonsils in children and irregular cartilage ossification in adults. In the newborn and young infant the tonsils and adenoids are normally sparse, and it is not until 6 months of age that lymphoid tissue can be identified radiographically in all children (Capitanio and Kirkpatrick, 1970). After this age the tonsils and adenoids can be small or considerably enlarged, encroaching on the nasopharynx or oropharynx and suggesting a pathologic soft tissue mass. In most cases these structures, even when large, are not abnormal and frequently are noted as incidental findings on skull or spine radiographs. Occasionally, however, they can be associated with airway obstruction (Fig. 97-3; Fernbach et al, 1983; Levy et al, 1967). In most instances, adenoidal size can be evaluated subjectively, but objective methods of assessing adenoidal size using an adenoidal/nasopharyngeal ratio have been described (Fujioka et al, 1979). The final decision as to whether adenoid or tonsillar tissue is of symptomatic importance is clinical not radiographic.

Cartilage of the neck can pose another problem in adults, since in certain patients, normal thyroid and cricoid calcifications can be irregular and incomplete, thereby simulating a foreign body or neoplastic destruction (Muroff and Seeman, 1974). These normal calcifications occasionally can be seen in older children, but as a rule the only cartilage calcified routinely in the younger child is the hyoid bone. Any other radiopaque structure usually is abnormal.

Inflammatory Disease of Larynx

Epiglottitis

The entire supraglottic airway may be involved in the inflammatory process, but the epiglottis and aryepiglottic folds are most extensively involved. These normally well-defined thin structures become edematous, enlarged, and unsharp, resulting in a rounded thumblike density in place of the epiglottis. The edema often encroaches on the vallecula and rarely may extend to the posterior pharyngeal wall. In addition, the hypopharynx and piriform sinuses usually are mildly to moderately overdistended (Capitanio and Kirkpatrick, 1968; Dunbar, 1961, 1970; Kushner and Harris, 1978). The remainder of the airway is fairly normal, although at least 25% of children with epiglottitis have subglottic narrowing (Shackelford et al, 1978).

The changes of epiglottitis are demonstrated best on the lateral radiograph (Fig. 97-4). Extensive manipulation of the patient should be avoided because of the possibility of inducing glottic spasm.

Enlargement of the epiglottis may result from a variety of other disorders including irritation from a foreign body or burn, tumors such as epiglottic cysts or neoplasms (for example, lymphoma), granulomatous disease (for example, sarcoidosis, tuberculosis, and Wegener's granulomatosis), and angioneurotic edema (McCook and Kirks, 1982; Slovis et al, 1979). The radiographic findings must therefore be correlated with the patient's clinical history (Fig. 97-5). On occasion, an omega epiglottis (a normal anatomic variation in children in which the epiglottis is floppy, vertically positioned, and omega shaped) may be misdiagnosed as epiglottitis (Swischuk, 1979). An important distinguishing feature is the absence of thickened aryepiglottic folds or other edematous changes.

Croup

Radiographic studies are not indicated or obtained routinely in patients with croup but are useful in confusing cases, primarily to exclude other causes of stridor. The radiographic changes are the result of inflammatory edema affecting the larynx and subglottic tissue. Radiographically the frontal view is most helpful in the diagnosis (Fig. 97-6). Symmetric subglottic airway narrowing or "pencilling" of the airway is the major radiographic finding (Capitanio and Kirkpatrick, 1968; Dunbar, 1961, 1970; Kushner and Harris, 1978). In contrast to patients with congenital subglottic stenosis, the narrowing of the subglottic portion of the trachea is not fixed and may improve on expiration (Swishuk et al, 1974). The lateral view of the neck appears less helpful, although the narrowing may be noted as well in this view. This projection demonstrates the presence of hypopharyngeal airway distension, but more importantly it establishes that the epiglottis and aryepiglottic folds are normal.

Membranous or bacterial croup and ordinary viral croup may present with similar symptoms, but unlike ordinary croup, membranous croup is characterized by diffuse inflammation of the larynx, trachea, and bronchi with adherent exudate and mucus on the surface of the upper tracheal mucosa (Han, 1979). Radiographs show subglottic narrowing and multiple tracheal soft tissue excrescences (Fig. 97-7). These intraluminal lesions can be mistaken for foreign bodies, so that clinical correlation is required for the diagnosis.

Retropharyngeal abscess

Retropharyngeal abscess results from suppuration of retropharyngeal lymph nodes in patients with upper respiratory tract infection or from perforation of the pharynx or upper esophagus by a foreign body. If the abscess compresses the larynx and upper trachea, symptoms of upper airway obstruction develop.

Lateral soft tissue radiographs of the neck will demonstrate fixed thickening of the retropharyngeal soft tissues, anterior displacement of the airway, reversal of normal cervical lordosis, and occasionally gas bubbles within the abscess (Fig. 97-8; Capitanio and Kirkpatrick, 1968; Dunbar, 1970; Swischuk et al, 1974. Fluoroscopy or a barium esophagram may be necessary to confirm that the radiographic changes are not those that occur with expiration or with the head in a flexed position.

CT and MRI superbly evaluate the retropharyngeal space. Suppurative adenopathy is usually limited to the suprahyoid region of this space and spares the midline. As infection becomes extranodal, the entire width of the retropharyngeal space frequently becomes thickened. Inflammation can then easily track into the infrahyoid region. The full extent of the process can be imaged by MRI or CT before therapy planning (Davis et al, 1990). Abscess will appear low density on CT, low signal intensity on T1-weighted MRI, and high signal intensity on T2-weighted MRI images, reflecting the presence of liquefaction.

Thickening of the retropharyngeal soft tissues also can occur secondary to bleeding and edema from cervical spine trauma, lymphadenopathy (for example, lymphoma, tuberculosis), or retropharyngeal tumors (for example, cystic hygroma, neuroblastoma, hemangioma, retropharyngeal goiter) (McCook and Felman, 1979; Swischuk et al, 1974). The imaging findings must therefore be correlated with the clinical history. If air bubbles are present within the mass, the diagnosis of a retropharyngeal abscess is more likely.

Laryngomalacia

Laryngomalacia or congenital flaccid larynx is one of the most common causes of inspiratory stridor in the neonate and young infant (Dunbar, 1970). Laryngoscopy demonstrates flaccidity of the epiglottis, aryepiglottic folds, or the entire larynx, which collapses during inspiration. The corresponding radiographic findings are best demonstrated with fluoroscopy. Hypopharyngeal overdistension with associated collapse of the aryepiglottic folds and epiglottis is observed on inspiration. Paradoxical narrowing of the subglottic portion of the airway may also be seen as the patient inspires. The primary reasons for doing laryngoscopy and radiography are to exclude other causes of congenital stridor, such as cysts, webs, tumors, and stenoses. In most children the symptoms disappear by 1 year of age.

Vocal Cord Paralysis

Although plain-film radiography, fluoroscopy, and computed tomography can evaluate vocal cord mobility, the diagnosis of abnormal vocal cord motion generally can be accomplished with laryngoscopy (Fig. 97-9; Gamsu et al, 1981; Williams et al, 1977). However, in those patients with vocal cord paralysis secondary to neoplasm, CT and more recently MRI have proven helpful in demonstrating the extent of neoplasm and its relationship to the adjacent cartilaginous structures (Jabour et al, 1990; Mnacuso et al, 1980). Plain chest radiography and thoracic CT are additional imaging methods that have proven helpful in detecting extralaryngeal masses impinging on the recurrent laryngeal nerve and resulting in vocal cord paralysis (Fig. 97-10; Glazer et al, 1983b).

Benign Laryngeal Masses

Benign neoplasms are addtional causes for respiratory obstruction. Symptoms and radiographic features depend on the tumor distribution and extent. Good-quality films of the larynx and upper trachea supplemented by high-kilovoltage magnification techniques are usually adequate in showing the intraluminal lesion.

Although rare in adults, subglottic hemangioma is the most common laryngeal and upper tracheal neoplasm in the newborn and young infant. The lesion typically appears as a well-defined mass in the posterior or lateral portion of the subglottic airway (Fig. 97-11; Slovis et al, 1979; Sutton and Nogrady, 1973). Although the subglottic narrowing is usually eccentric, circumferential narrowing suggestive of croup may be seen. Hemangiomas may occur on the skin or elsewhere in the body in affected patients.

Squamous papillomas, the most frequent laryngeal tumors in the older infant and child, have also been reported in adults (Felson, 1983; Greenfield and Herman, 1963). The radiographic appearance of papillomatosis is contingent on the size and location of the lesions.

Generally single or multiple intraluminal soft tissue nodules are seen in the glottis or in the tracheal air column (Fig. 97-12). Although bronchography has been used in demonstrating papillomas, it has generally been replaced by laryngoscopy and bronchoscopy. Since papillomas may extend to the bronchial tree or pulmonary parenchyma, plain chest radiographs are extremely important in defining the extent of disease. Localized areas of atelectasis, air trapping, or pneumonia have all been reported. Papillomas also may appear as well-defined discrete pulmonary nodules that eventually cavitate, forming multiple thin-walled cystic lesions (Kramer et al, 1985; Smith and Gooding, 1974).

A laryngocele is an abnormal elongation and expansion of the saccule of the laryngeal ventricle (Holinger and Brown, 1967). If it remains confined within the paralaryngeal space, it presents on laryngoscopy as a soft, localized bulge of the aryepiglottic fold; when it extends through the thyrohyoid membrane into the subcutaneous tissues of the neck it can present as a localized mass in the side of the neck. Regardless of position, laryngoceles are usually visualized as sharply defined air-containing structures on soft tissue radiography or tomography of the neck (Fig. 97-13; Lindell et al, 1978). If they contain fluid, they appear as a soft tissue mass. A modified Valsalva maneuver occasionally improves their visualization. Since air-containing laryngoceles communicate with the laryngeal ventricle, they may fill during contrast laryngography. CT can be helpful in showing fluid-containing as well as air-containing laryngoceles (Figs. 97-14 and 97-15; Glazer et al, 1983a). If the mass is of soft tissue density because it contains either mucoid or purulent material, the distinction from neoplasm may be more difficult. However, its location and smooth surface in conjunction with a normal mucosa on laryngoscopy should suggest a laryngocele. CT also may be helpful in demonstrating the external component of a laryngocele that is not apparent on physical examination.

Congenital cysts of the larynx are rare causes of respiratory obstruction in infants. They most commonly arise in the region of the epiglottis or aryepiglottic fold. Plain-film examination of the airway will disclose a soft tissue mass of varying size, encroaching on and displacing the normal airway.

Laryngeal Carcinoma

Nearly all mucosal tumors are diagnosed by direct inspection and biopsy; the role of imaging is to provide crucial information about involvement of deep structures such as the paralaryngeal space, cartilage, and lymph nodes.

CT is a proven imaging technique for evaluating patients with laryngeal carcinoma (Archer et al, 1981; Mancuso and Hanafee, 1979a; Sagel et al, 1981; Scott et al, 1981; Sulfaro et al, 1989). In most patients CT will demonstrate more extensive disease than is initially appreciated by laryngoscopy and other radiologic procedures, including contrast laryngography, conventional tomography, and plain-film radiography. The latter modalities give similar information to that of laryngoscopy, primarily showing alteration of the air column and mucosal surfaces. The cross-sectional imaging provided by CT, however, allows evaluation of the intrinsic and deep soft tissues of the larynx as well as the cartilaginous skeleton.

The newly developed technology of MRI is rapidly becoming an alternative to CT for imaging laryngeal anatomy (Hoover et al, 1987). Advantages of MRI include its excellent soft tissue contrast, which is superior to CT. Multiplanar display enables coronal, transverse, and sagittal anatomic formatting, whereas CT is usually limited to the transverse plane. MRI uses no ionizing radiation and is not plagued by annoying artifacts caused by beam hardening, dental amalgam, or poor beam penetration of the shoulders. MRI does have limitations, however. It is slower than CT, and therefore patient motion can seriously degrade images. This must be especially considered when choosing a modality in laryngeal cancer patients who are often elderly and may have other medical problems, such as chronic obstructive pulmonary disease. MRI does not image cortical bone or calcifications well. Further, MRI is contraindicated in patients with cardiac pacemakers and cerebral aneurysm clips.

The decision for selecting radiation therapy, coservation surgery, or total laryngectomy depends on an accurate delineation of tumor extent (Lesinski et al, 1976; Ogura and Heeneman, 1973). CT and MRI are excellent noninvasive methods capable of three-dimensional anatomic display of those portions of the larynx that are not well examined by laryngoscopy. Submucosal extension of tumor and cartilaginous destruction that are not suspected clinically can be assessed. Although MRI has been impressive, its overal superiority for laryngeal imaging has not been definitely established, and the choice of either CT or MRI must be tailored to the patient. Further, imaging is not a substitute for, but rather is complementary to, laryngoscopy. Although imaging may demonstrate advanced mucosal abnormalities, minor mucosal abnormalities and abnormalities of intrinsic motion are best studied by laryngoscopy (Mancuso and Hanafee, 1985).

Neoplasm is identifiable on CT as an area of increased soft tissue density that alters the normal symmetric laryngeal anatomy. Similarly, the hallmark of an abnormal larynx on MRI is asymmetry. The superb soft tissue contrast provides additional information. On T1-weighted images, fat is high signal intensity and differs significantly from the mucosa and muscles in appearance. Lymph nodes and infiltrating tumor, which are lower in signal intensity than fat, are well visualized on T1-weighted images. On T2-weighted images, muscle is lower in signal intensity than mucosa, fat, and many tumors. Carcinomas within the mucosa and muscles can be well delineated (Dillon, 1986). Neither CT nor MRI findings are specific histologically and can be seen in hemorrhage, edema, inflammation, or fibrosis. Therefore the examination must be correlated with the clinical history and should be performed before laryngeal biopsy or at least 48 hours after biopsy to avoid confusion with postbiopsy edema and hemorrhage.

Technique

The examination is best performed with CT scanners that provide narrowly collimated sections (3 mm) and rapid scanning times (less than 5 seconds). Thin sections (1.5 to 2 mm) can provide additional information about specific regions such as the anterior commissure (Silverman et al, 1982). Iodinated contrast is administered intravenously to distinguish nonenhancing lymph nodes from enhancing vessels. Contiguous images are obtained during slow inspiration. If the images are performed during suspended inspiration, adduction of the true vocal cords may cause the airway to appear falsely narrowed. Scans occasionally are obtained during phonation ("e") or a modified Valsalva maneuver to distend the piriform sinuses and improve visualization of the aryepiglottic folds.

MRI techniques may vary depending on scanner type and available hardware and software. Surface coils are essential to adequate imaging of the larynx (Jabour et al, 1990; Lufkin and Hanafee, 1985). Sagittal, transverse, and coronal T1-weighted images best display anatomic relationships. Balanced and T2-weighted transverse images are necessary to further define the signal characteristics of the tissues. Sections are usually 3 to 5 mm thick; gaps of 1 mm between sections improve individual slice quality. Applications of the paramagnetic contrast agent gadopentetate dimeglumine in neck imaging are being explored (Robinson et al, 1989).

Normal anatomy

Accurate interpretation of scans of the larynx necessitates understanding normal laryngeal anatomy as depicted on CT or MRI (Figs. 97-16 to 97-23). Although laryngeal symmetry is helpful in the evaluation of patients with suspected laryngeal abnormalities, there is some degree of normal asymmetry that must be recognized in order to avoid misinterpretation.

The laryngeal skeleton consists of the hyoid bone and the epiglottic, thyroid, arytenoid, and cricoid cartilages. Their unique appearance allows for easy orientation of the CT scans. A large amount of variation in the degree of cartilaginous mineralization normally can occur. In particular, calcification of the thyroid cartilage may be irregular and incomplete, simulating neoplastic invasion. The calcified or ossified portions of the laryngeal skeleton are low signal on MRI. Noncalcified cartilage, such as the epiglottis, is intermediate in signal intensity. Fat within medullary spaces is high signal intensity on T1-weighted sequences.

The intrinsic soft tissue structures of the larynx include the aryepiglottic folds, true vocal cords, and false vocal cords. The aryepiglottic folds, which form the medial walls of the piriform sinuses, extend obliquely from the top of the epiglottis toward the false cords inferiorly (Figs. 97-16 and 97-17). Although the aryepiglottic folds may be asymmetric during inspiration, distension of the piriform sinuses during a modified Valsalva maneuver or phonation will result in a more symmetric appearance.

The piriform sinuses are bilateral air-containing structures bulging into the paralaryngeal spaces (Figs. 97-16 and 97-17). They are partially collapsed during quiet breathing but distend during a modified Valsalva maneuver or phonation. The piriform sinuses are frequently asymmetric on scans both in their size and their caudal extent.

The true vocal cords are visualized in an abducted position during slow inspiration (Figs. 97-18 and 97-19). They are triangular in shape and wider posteriorly, measuring about 9 mm in thickness. The posterior commissure is located in this area between the vocal processes of the arytenoids. Anteriorly at the anterior commissure, where the true vocal cords meet and attach to the thyroid cartilage, the thickness tapers to 2 mm. Only minimal (not greater than 1 to 2 mm) soft tissue thickening should be seen in the area of either the anterior or posterior commissure. If the cords are adducted, the soft tissues in the region of both anterior and posterior commissures may appear falsely thickened.

The false vocal cords appear as a thicker band of soft tissue at the level where the foot processes of the arytenoids are present (Fig. 97-18). In contrast to the region of the anterior commissure and true vocal cords, there is normally appreciable soft tissue thickening anteriorly behind the thyroid lamina, in part due to insertion of the thyroepiglottic ligament. The laryngeal ventricle separating the true and false vocal cords is visualized only in 10% of patients because of partial volume averaging. The use of a reverse "e" maneuver may improve visualization of the laryngeal ventricle.

The soft tissue (preepiglottic and paralaryngeal spaces) deep to the endolarynx is well visualized on CT because it is composed primarily of fat. Consequently it is of lower density than the true vocal cords or neoplasm (see Fig. 97-16). On MRI, these spaces display relatively high signal intensity on T1- and T2-weighted images, reflecting the fat composition (Figs. 97-17 and 97-20).

The laryngeal airway has different shapes at different levels. The laryngeal vestibule or supraglottic portion of the airway is elliptic in shape with a long lateral axis. The anteroposterior dimension of the airway increases at the level of the true vocal cords. The subglottic region has a circular configuration with a flap posterior border at the level of the trachea. The cricoid ring indicates the level of the subglottic space. In this area no detectable soft tissue should be seen on CT or MRI between the inner surface of the cricoid cartilage and the airway (Figs. 97-21 and 97-22).

The jugular veins and carotid arteries can be clearly visualized posterolateral to the thyroid laminae. The right jugular vein, which is usually larger than the left, may be confused both on CT and on physical examination with lymphadenopathy. In such cases, scanning performed after administration of intravenous contrast will improve identification of the normal vascular structures. Rapidly flowing blood within the jugular vein and carotid arteries is devoid of signal on MRI and therefore can be easily separated from soft tissue structures.

Glottic tumors

Vocal cord carcinomas that are confined to a normally mobile true vocal cord may be treated with radiation therapy, laser, cordectomy, or partial laryngectomy (Mancuso and Hanafee, 1985; Ogura and Heeneman, 1973). In these cases CT scans may be normal or show nonspecific focal or diffuse vocal cord thickening (Fig. 97-24). If the true cord is fixed in the midline, the role of CT is in demonstrating deep infiltration of tumor before surgery (Mancuso et al, 1980). CT cannot distinguish whether the cord is paramedian in position because of paralysis or direct involvement with tumor. MRI may be helpful in this determination because of its superior soft tissue contrast. Nevertheless, signal characteristics are often nonspecific. CT will occasionally show that vocal cord fixation or a laryngeal mass is secondary to prior occult trauma and the laryngeal neoplasm is less extensive than suspected clinically.

Glottic tumors spread anteriorly, posteriorly, inferiorly, or laterally into the paralaryngeal space. The primary role of imaging in patients with true vocal cord neoplasms is in the evaluation of the anterior and posterior commissures, the paralaryngeal and subglottic spaces, and the thyroid and cricoid cartilages. Both CT and MRI are very reliable in demonstrating tumor involvement at these sites. If there is involvement of greater than 30% of the contralateral true vocal cord, thyroid cartilage invasion, or subglottic extension of tumor, partial laryngectomy is generally contraindicated (Mancuso and Hanafee, 1985; Ogura and Heeneman, 1973).

Tumors can extend anteriorly to the anterior commissure and posteriorly to the arytenoid cartilage, posterior commissure, and cricoarytenoid joint (Fig. 97-25). The identification of air abutting the thyroid cartilage at the anterior commissure on transverse images shows there is no tumor in this area. Any increase in soft tissue in this area should be considered abnormal and suspicious of tumor extension. Once tumor has reached the anterior commissure it can grow into the thyroid cartilage, preepiglottic space, opposite vocal cord, or subglottic space (Kirchner, 1977). Care should be taken to avoid misdiagnoses of anterior tumor spread caused by various normal cord configurations that occur in different phases of respiration. Neoplasm that has reached the posterior commissure will result in soft tissue thickening over the arytenoid cartilages; rotation or displacement of the arytenoid cartilages may also occur.

The radiologic diagnosis of subglottic tumor is made by determining the relationship of the tumor mass to the level of the true cords (Fig. 97-26). Exophytic tumor will distort the tracheal air column (Fig. 97-27). If the extent of tumor caudad from the inferior margin of true vocal cords is greater than 1 cm anteriorly and 6 mm posteriorly, total laryngectomy may be indicated (Kirchner, 1977; Ogura and Heeneman, 1973). However, the relationship between the subglottic tumor and the cricoid cartilage is more important than a standard measurement, since the cricoid cartilage provides critical support for the larynx. On CT and MRI there is normally no measureable soft tissue thickness between the cricoid cartilage and the airway. An additional advantage of MRI is the capability of imaging in the coronal plane, which allows tracing of tumor extension below the level of the conus elasticus (Curing, 1989).

Imaging also demonstrates spread of laryngeal carcinoma into the paralaryngeal space. Although a thin line of fat density may be seen medial to the thyroid cartilage at the level of the true vocal cords, the paralaryngeal space is wider in the area of the false vocal cord (Shulman et al, 1982). Therefore extension into the paralaryngeal area is easier to demonstrate at this level. CT, however, may not be able to determine extension into the false vocal cord itself; this is evaluated better by laryngoscopy. Coronal MRI is helpful for paralaryngeal evaluation.

CT and MRI are both excellent methods for demonstrating cartilaginous invasion by laryngeal carcinoma, although limitations exist (Archer and Yeager, 1979; Castelijns, 1987b; Mafee et al, 1983). Since the thyroid cartilage normally may have an irregular pattern of calcificatio and ossification, neoplastic involvement can be confidently diagnosed only when advanced. On CT, marked destruction of the cartilage appears as fragmentation of the cartilage with lateral extension of soft tissue tumor (Fig. 97-28). Cartilage involvement may also be suggested by abnormal bowing of the thyroid cartilage. On MRI, cortical bone and dense calcification have no signal on either T1-weighted or T2-weighted sequences. However, the medulary fat has a bright signal on T1-weighted images. Invasion of fat lowers this signal and can be further differentiated from nonossified cartilage on balanced and T2-weighted images because of the brighter signal displayed by tumor (Fig. 97-29; Castelijns et al, 1987b, 1990). If the imaging findings are equivocal, biopsy of the cartilage is recommended to confirm the need for radical surgery.

Supraglottic tumors

Carcinoma of the epiglottis is seen on imaging as thickening of one of the margins of the epiglottis or as a large soft tissue mass (Figs. 97-30 and 97-31). Localized carcinoma of the epiglottis may be treated with radiation therapy or a supraglottic laryngectomy (Cocke and Wang, 1976). However, if there is invasion of the preepiglottic space, radiation treatment alone is considered inadequate therapy (Klein and Fletcher, 1964). Such extension of epiglottic carcinoma to the preepiglottic space is frequently difficult to demonstrate clinically or with contrast laryngography. Both CT and MRI are helpful in evaluating the preepiglottic and paralaryngeal spaces, since infiltrating tumors usually obliterate the normal appearance of fat in these areas (Figs. 97-32 and 97-33; Curtin, 1989). Transversely oriented CT or MRI slices are helpful when the cords and the space immediately superior to the cords are normal. Similarly, transverse slices are useful when the cords are unequivocally involved. In patients with supraglottic disease that approaches the ventricles but in whom transverse imaging does not clearly depict the ventricle, coronal MRI emerges as the best study (Curtin, 1989). CT and MRI can also demonstrate deep spread of tumor into the region of the anterior commissure. Spread of tumor into the base of the tongue is best evaluated by sagittal MRI.

Carcinoma of the aryepiglottic fold is recognizable by thickening of the aryepiglottic fold. This is often better demonstrated on scans perforemd during phonation or a modified Valsalva maneuver (Fig. 97-34). CT scans obtained during phonation will show distension of the piriform sinuses and thinning of the normal aryepiglottic fold, allowing for easier CT demonstration of tumor. If there is tumor extension anteriorly across the midline, it may be difficult on imaging studies to determine whether the tumor originates in the aryepiglottic fold or in the epiglottis.

Neoplasms of the piriform sinus generally are more aggressive than lesions arising in the endolarynx, having a high incidence of thyroid cartilage invasion. They may also spread to the true and false vocal cords, aryepiglottic folds, and preepiglottic space. CT or MRI can demonstrate tumor spread outside the larynx between the thyroid and cricoid cartilages. This appearance usually is seen only with piriform sinus tumors (Fig. 97-35; Larrson et al, 1981).

Transglottic tumors

Transglottic tumors extend across the laryngeal ventricle to involve the supraglottic, glottic, and often the subglottic portions of the larynx (Fig. 97-35; Tucker, 1974). This extension of tumor may be mucosal or submucosal. Transglottic tumors demonstrate a very high incidence of thyroid cartilage destruction and extralaryngeal spread that may not be apparent clinically. Coronal MRI may better demonstrate spread of tumor than axial images.

Lymph nodes

Most enlarged lymph nodes identified on CT are clinically palpable, but occasionally CT may demonstrate enlarged lymph nodes that cannot be felt on physical examination (Mancuso et al, 1981). Imaging is also helpful in showing the relationship of enlarged lymph nodes or tumor extension to adjacent vessels (Fig. 97-36). Surgical salvage is less likely if neoplasm totally encases or invades vascular structures. (For a detailed discussion of cervical lymphadenopathy, see Chapter 98.)

Postoperative larynx

Physical examination in patients who have undergone prior irradiation or surgery may be difficult because of alteration of the normal laryngeal anatomy and swelling of the adjacent soft tissues. CT can define the anatomy of the postoperative larynx and assist laryngoscopy in the detection or recurrent neoplasm (Fig. 97-37; DiSanti et al, 1984a, 1984b; Niemeyer et al, 1987; Som and Biller, 1983). When anatomic landmarks are inadequately demonstrated on CT, MRI becomes a reasonable alternative technique (Glazer et al, 1986). In patients with lesions prone to recur, a baseline study 6 to 8 weeks after therapy is helpful (Mancuso and Hanafee, 1985).

In patients with previous vertical hemilaryngectomy, recurrent intralaryngeal cancer is suggested by increased width of the contralateral true vocal cord, convexity of the postsurgical pseudocord at the glottic level, mass in the subglottic region, or masses in the extralaryngeal neck (DiSantis et al, 1984a). In patients with supraglottic subtotal laryngectomy, recurrence is usually heralded by mass effect on the pharyngeal or laryngeal air column, obliteration of the adjacent soft tissue planes, destruction of cartilage, or development of lymphadenopathy (Niemeyer et al, 1987). CT signs of recurrence in patients who have undergone total laryngectomy include masses involving the internal jugular lymph node chain adjacent to the neopharynx or neurovascular bundle, masses within the mediastinum, thickening of the tracheal wall, or thickening of the soft tissues surrounding the tracheostomy (DiSantis et al, 1984b). Nodular masses in the surgical sites of patients with radical neck dissection are unusual and should prompt evaluation for tumor (Som and Biller, 1983). Care must be taken in radiographically evaluating the postoperative patient because abscess or granulation tissue can mimic recurrent tumor (DiSantis et al, 1984a).

Radiation therapy can also change the appearance of the neck on imaging studies. The subcutaneous fat becomes thickened and streaked with linear soft tissue densities at doses of 6800 to 7000 cGy. The skin also may become thickened. Above 7000 cGy, the pharyngeal walls and aryepiglottic folds become thickened as the paralaryngeal and preepiglottic spaces increase in CT density. Intralaryngeal edema may be symmetric or asymmetric and therefore offers no definitive criteria for tumor recurrences (Mancuso and Hanafee, 1985). On MRI, evidence suggests that signal intensity of tumor tends to diminish with successful radiation therapy and the subsequent development of fibrosis (Glazer et al, 1986). Residual tumor usually maintains a high signal intensity; however, similar nonspecific signal intensities also can be produced by edema, hyperplastic lymphadenopathy, infection, and hemorrhage (Glazer et al, 1986). Differentiation between fibrosis and early recurrent tumor still requires laryngoscopic biopsy.

Chondronecrosis, a rare sequela of radiation therapy, is difficult to differentiate from recurrent tumor on CT. The soft tissues are thickened, and cartilages may be distorted or fragmented (Mancuso and Hanafee, 1985).

Laryngeal Trauma

Although conventional frontal and lateral radiographs can provide useful information about the injured larynx, CT is capable of greater precision in demonstrating the extent of disruption (Mancuso and Hanafee, 1979b, 1985; Schaefer and Close 1989). Cross-sectional imaging allows easy and rapid evaluation of the extent of cartilaginous injury, adjacent soft tissue changes such as edema or hemorrhage, and the degree of airway compromise (Figs. 97-38 and 97-39). CT is especially useful in patients with marked supraglottic swelling that prevents adequate laryngoscopic evaluation.

Laryngeal injuries from blunt trauma include fracture, displacement, or dislocation of the individual cartilages. CT can accurately identify transverse or vertical fractures of the thyroid or cricoid cartilage, dislocation of the arytentoid cartilages at the cricoarytenoid joint, and disruption of the cricothyroid joint, as well as extensive hemorrhage obliterating the airway. On occasion, the normal thyroid notch may be mistaken for a fracture, although contiguous sections usually provide the correct diagnosis.

Pharyngeal perforation is a rare but known complication of endotracheal intubation (Dawkes, 1964; Hirsch et al, 1978). Radiographs of the area often will demonstrate air within the retropharyngeal soft tissues or in the anterior mediastinum. Oral contrast studies of the esophagus may be useful in defining the problems related to perforation, including the subsequent development of a pseudodiverticulum.

Foreign Bodies

Foreign bodies lodged in the larynx, trachea, or esophagus should be considered in patients, particularly children, with symptoms of acute or recurrent airway disease (Newman, 1978; Smith et al, 1974). The radiopaque ones obviously are readily diagnosed (Fig. 97-40). With plain-film techniques, including high-kilovoltage radiography, non-opaque foreign bodies also may be identified at times. The radiographic findings of aspirated foreign bodies vary directly with the location and extent of obstruction. On occasion, calcification of the laryngeal cartilages or of the stylohyoid ligaments may be confused with aspirated foreign bodies, although oblique projections usually permit separation (Fig. 97-41; Muroff and Seeman, 1974).

In patients with suspected aspiration of a foreign body and a normal examination of the upper airway, inspiratory-expiratory plain chest radiographs or decubitus chest radiographs should be performed. These may demonstrate regional obstructive emphysema resulting from aspirated foreign bodies in the bronchi (Capitanio and Kirkpatrick, 1968, 1972). In uncooperative patients, fluoroscopic examination of diagphragmatic and mediastinal excursions may be helpful in determining if air trapping is present.

Swallowed foreign bodies lodged in the upper esophagus may produce airway obstruction by compressing the posterior wall of the larynx and trachea. Tracheal compression, appreciated best on the lateral radiograph, is the expected radiographic finding. A barium esophagram is the definitive procedure in disclosing the occult esophageal foreign body (Fig. 97-42; Smith et al, 1974). If the object erodes through the esophageal wall, a retropharyngeal abscess may form with resulting compression of the adjacent airway.